Conference Paper

COMPARISON OF INSULATOR TYPES
BY THE
WET CONTAMINANT AND CLEAN FOG TEST METHODS

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ABSTRACT

Withstand and flashover test data are presented for five types of insulators tested by the clean fog method and the wet contaminant method. The insulators were contaminated with a slurry having the proportions of 1 liter of water, 20 grams of Cab-O-Sil**, 1 gram of Photo-Flo**, and various quantities of salt to obtain the desired conductivities. The present data are also compared with those obtained by other investigators.

INTRODUCTION

In reference (1) the results of an investigation which culminated in the proposal of a new contamination test method were reported. Along with the proposed test, called the "Wet Contaminant Method", a new contaminating slurry composed of Cab-O-Sil**, Photo-Flo**, and salt was introduced. At the conclusion of the investigation, in order to further evaluate the new method, a large number of tests were performed to compare the withstand strengths of several types of insulators with both the "Wet Contaminant" and "Clean Fog" test methods. The new contaminating mixture was used for both testing methods.

The insulators tested were:

A. EIV high creepage glass disk, #67
B. Locke fog disk, Cat. #18134
C. Locke standard disk, Cat. #1840

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* - B. Macchiaroli was in the High Voltage Laboratory of General Electric Co., Pittsfield, Massachusetts on a NATO-CNR scholarship.

** - Trade name.

D. Richard Ginori fog long rod model 52486

E. Richard Ginori standard long rod model 52425

In each case the number of insulators was selected so that the overall lengths were roughly the same. Also, it was desired to use the same length of insulator strings as other investigators, (2) & (3), so that the data could be directly compared. The characteristics of the insulator strings tested are given in Table I and Figure 1.

The power sources used throughout the testing had short circuit currents of 10 amperes or more at the voltages employed.

TEST METHODS

Wet Contaminant Method:

The complete test procedure and the characteristics of the wet contaminant test method are detailed in a paper(1) by the authors so only the essential points will be summarized here.

The contaminating mixture used for the present tests is that which gave the best results in the former investigation, namely:

Cab-O-Sil	20 g/l
Photo-Flo 600	1 g/l
NaCl	2 to 20 g/l

For each test the insulators are washed in a neutral detergent, rinsed with tap water, and dried with compressed air. The insulators are then flow-coated with multiple streams of the prepared mixture that coat the complete surface to the point of run-off.

Three to five minutes after the end of flow-coating, while the insulators are still wet, voltage is applied and increased with a constant rate of 7.5 kV/s. In the first test the voltage is increased until flashover, whereas in subsequent tests an attempt is made to hold a withstand voltage below the preceding flashover level. For each withstand test the voltage is held at a predetermined level until current pulses and visual activity cease. The test is repeated several times until the highest level is determined at which three withstands and no flashover are obtained. This is called the withstand voltage for the particular degree of contamination and is determined within five percent.

The pollution degree can be measured in four different ways: by the salt content in the slurry, by the conductivity of the slurry, by the average salt deposit density on the insulators, or by the surface conductivity of the insulators.

In the present investigation, in order to have complete data for comparing the test results, all the above methods of measuring the pollution severity were used.

Clean Fog Method:

The concept of using a clean fog to deposit moisture on a contaminated string was first developed in Germany, and now is used in several other countries. However, although this method is being used by many investigators, the type of contaminant, the parameter for measuring the degree of pollution, and the test procedure are generally different.

For the present tests the same contaminating mixture was used as for the preceding wet contaminant method, but it was found necessary to use higher salt concentrations in order to achieve the same surface conductivities. This is due to the greater degree of "wetness" achieved with the wet contaminant method.

Before applying the contaminant to the insulators they were washed with a neutral detergent, rinsed with tap water, and dried with compressed air as before. They were then spray coated with the contaminant as uniformly as possible and allowed to dry. The dry string of insulators was then hung in a large tent made of polyethylene sheet material. This tent and the complete setup for the clean fog tests are shown in Figure 2.

Working with a spray system for contaminating insulators, and fog in a tent to wet them, there is necessarily a large number of variables. In order to reduce them to a minimum, conditions were held as constant as possible for each operation. The pressure on the spraying gun was maintained constant as were also the water and air pressure for the fog. These were 2 kg/cm^2 for the water and 6 kg/cm^2 for the air. Visibility inside the fog tent was less than three meters. The resistivity of the water used for the fog was 18,000 ohm-cm.

From preceding experimental work it was found that flashover data obtained in the fog tent correlated quite well with surface conductivity measurements made just prior to applying the test voltage. These surface conductivity measurements were made by applying a low voltage and monitoring the leakage current versus time. Very erratic results can be obtained in this measurement unless some provision is made to insure a fairly uniform wetting of the insulators. It was found that this could be accomplished in two ways: 1) by exposing the insulators in the fog tent until the fog becomes dense and then spraying the dry areas with a hand spray gun using water having the same resistivity as that used for the fog, and 2) by placing a high speed fan in the corner of the fog tent directed so that it blows the fog up under the insulator skirts. Tests were made with both of these methods and it was found that they are roughly equivalent. In each case, the leakage current will rise to a maximum value at which it will remain steady for a period of time, and then slowly decrease due to the washing action of the fog.

Accordingly, in performing the present clean fog tests, an arrangement was made that allowed the conductivity to be measured for each insulator string. This was accomplished by the use of two power sources and a high voltage switch with which either source could be selected. Initially, the low voltage source was connected to the insulators under test, the fog turned on, and the leakage current monitored until it reached a steady value. At this time the switch was changed over to the high voltage power source, and the withstand or flashover test conducted.

For conducting the high voltage tests, the voltage was increased to some predetermined value, held constant for ten minutes, and then if no flashover had occurred, increased by ten percent and held for five minutes. If in the last voltage level a flashover occurred, the preceding level held for ten minutes was assumed to be the maximum withstand. If no flashover occurred, the insulators were cleaned and recontaminated and the test was repeated at a ten percent higher voltage. This process was repeated until the maximum withstand voltage was determined for a given surface conductivity.

The degree of contamination was measured in two ways: 1) by measuring the surface conductivity just prior to applying high voltage, and 2) by measuring the salt deposit density on the insulator surfaces both before and after test. There was an appreciable difference in the before and after test results due to the washing action of the fog. Since, because of the test method adopted, an appreciable time elapsed with the fog on before the high voltage was applied, it was decided that the salt on the insulators after test was more representative of that present during the critical time of high voltage application; therefore, the "after test value" was the one recorded in this paper.

TEST RESULTS

Wet Contaminant Method:

The test results obtained with the five different kinds of insulators are summarized in Figures 3 through 6 in which the withstand voltage is plotted versus the amount of salt in the slurry, the conductivity of the slurry, the total salt deposit density, and the surface conductivity. The curves for the standard and fog disk units are from the preceding paper(1) by the authors.

For comparing different strings many criteria could be used. As stated in the introduction, the insulator string lengths were selected so that results could be directly compared with investigations (2) and (3). Therefore, for the same reason a voltage of 84 kV line-to-ground will be used to compare the ability of the insulator strings to withstand pollution. All of the measured values of pollution severity corresponding to a withstand voltage of 84 kV are recorded in Table II. In this table the insulators are listed in the order of merit, the electrically strongest one being first, and the ratios of the tabulated quantities for each insulator type to those for the strongest have been computed.

The order of merit of the insulators is the same regardless of which of the parameters is selected for measuring the degree of pollution. The ratios calculated vary somewhat going across Table II, but not to a significant degree, with two exceptions. These are for the salt deposit density on the long rods and surface conductivity of the fog and standard disk. The relatively superior performance of the high creepage glass disk to the fog disk on the basis of surface conductivity is hard to explain, since the salt in the slurry, the slurry conductivity and salt deposit ratios are in agreement. For some unknown reason the surface conductivity of the glass units became greater than that of the porcelain for an equivalent salt deposit density.

In regard to the long rod insulators, the ratios for salt deposit density and surface conductivity are in agreement, but both are quite low in relation to the ratios for the slurry properties. This seems to indicate that the salt did not adhere as well to the long rod surfaces.

Throughout the testing it was observed that the long rod insulators behaved differently than the disk type. Whereas for the disk type insulators the variation in the surface conductivity for a particular slurry was 2%, for the long rod it was about 5%. Also the variability in the withstand and flashover data for the long rod insulators was very high; the flashover voltage varied as much as 40% for the fog type. Often, after obtaining a withstand value at a given level, a flashover occurred on a succeeding test at a level 10% or 15% lower. It was also noticed that the scintillation activity was different for the long rod insulators than the disk. Whereas for the disk type arcing starts off of the cap and pin, for the long rod there is activity between the skirts, and generally not on the body. Also, when attempting to hold a withstand level, a flashover may occur after several minutes, whereas with the disk type it usually occurs within a half minute.

The variable behavior of the long rod insulators was ascertained by a large number of tests, about one hundred total for the fog long rod. The final withstand values plotted on the curves are the highest levels at which three withstands were obtained below the lowest flashover voltage.

Clean Fog Method:

The effect of the two different methods of wetting on the withstand and flashover voltages is shown for each type of insulator in Figures 7 through 11, using salt deposit density as the measurement of pollution severity and in Figures 12 through 16, using surface conductivity as the pollution measurement.

Referring to the graphs it is seen that there is a greater dispersion in the results when plotted against salt deposit density than when plotted against surface conductivity. This is understandable, since the withstand strength is dependent upon both the amount of salt on the surface and the degree of wetness, and both of these quantities also affect the surface conductivity. Even though the fog is maintained as uniform as possible, there is always considerable variation in the degree of wetness among the insulators of a string. The surface conductivity measurement inherently reflects this variability in wetness, and thus correlates quite well with the withstand and flashover values. The only exceptions to this were with the long rod insulators at low and high surface conductivity (about 15 µS and 70 µS).

Because the wet contaminant method can be performed in a short time, it was possible to make many replications. The clean fog method is much more time consuming and fewer replications were made. It is quite possible that if the same number of tests had been made for each method, there would have been better agreement at low and high surface conductivity.

The tests with the fan and those in which the insulators were wetted underneath by hand spraying gave about the same results. Evidently once the surface was thoroughly wet underneath by spraying, additional water was not required from the fog.

Sometimes there was an appreciable variation in the salt deposit density and surface conductivity among insulator strings contaminated by spraying with the same slurry. This reflects the inability of an operator to judge the thickness of the coating and is one of the reasons that the flow-coat method was adopted for the wet contaminant test. Originally it was intended to dip the insulators for the clean fog tests, but this was found to be impractical with fog type insulators because of the difficulty in attaching them together without damaging the coating.

In Figures 17 and 18 the curves for the various insulators are summarized for comparison. From these curves the values of salt deposit density and surface conductivity corresponding to a withstand voltage of 84 kV have been read and tabulated in Table III. As for the wet contaminant method, the ratios have been calculated with respect to the electrically strongest insulator, which is again the high creepage glass disk.

The order of merit of the insulators is seen to be the same when either the salt deposit density or the surface conductivity is used as a basis for comparison, but the ratios are quite different. As with the wet contaminant method, the high creepage glass disk insulators show a greater superiority when compared on the basis of surface conductivity.

In Table IV are tabulated the average times that were required for the insulators to reach a steady value of surface conductivity. These times varied from test to test and generally increased with the amount of salt. It can be seen that the insulators with the most complex contours took the longest time to stabilize. Also the stabilizing times vary in the same order as the rating of the insulators by the wet contaminant method.

DISCUSSION OF TEST RESULTS

Throughout the tests, measurements were recorded of all the parameters affecting the degree of contamination so that they would be available for comparison both for the two methods investigated and also with the work of other investigators.

The order of merit of the insulators at a withstand voltage of 84 kV is listed in Tables II and III where it can be seen that the clean fog and the wet contaminant test methods result in the same ranking except for the fog long rod unit. In this case the wet contaminant method rates it fourth, whereas the clean fog method rates it second. As already mentioned there was a large dispersion in the data for the long rod insulators, and a large number of tests were performed with the wet contaminant method. This was not possible with the fog method, and this perhaps explains the difference.

This difference in performance of the fog long rod as evaluated by the two test methods existed over the entire range of test voltages as can be seen by comparing Figures 5 and 6 with 17 and 18.

In order to compare the severity of the two test methods, the salt deposit densities corresponding to a withstand voltage of 84 kV were summarized for the five types of insulators in Table V. It is apparent from these values that the wet contaminant method is the more severe of the two tests in that it requires a much lower salt density to reduce the withstand voltage to 84 kV. For the three types of disk insulators, however, there is a constant ratio between the two test methods indicating that they are really equivalent. The fog long rod and standard long rod insulators have different ratios which is probably due, as already mentioned, to the large variation in the data and the lack of time for making enough tests with the clean fog test method.

These same general observations also apply to Table VI where the insulators are ranked according to the conductivity corresponding to a withstand of 84 kV. There is one difference, however, in that the conductivities for a given type of disk insulator are practically identical for the two test methods, whereas the salt deposit densities were higher for the clean fog method. This can be explained as follows. The conductivity is dependent upon both the salt density and the wetness of the surface. Since the surface wetness is greater for the wet contaminant test, less salt is required to reach the same level of conductivity. Thus for a withstand value of 84 kV, it is possible to have the same conductivity measurement for the two test methods but have different salt densities.

Summarizing the results for the two test methods, it can be said that there is very good agreement between them in all respects for tests on the disk type insulators, but that the wet contaminant method rates the long rod insulators much lower than does the clean fog method. Among the disk units, the order is very much as expected with the high creepage glass first, the fog type second, and the standard third. It is possible that if a sufficient number of tests were performed by the fog method on the long rod units, they would also be in the same order as found with the wet contaminant method.

COMPARISON WITH OTHER INVESTIGATIONS

In references (2) and (3) results are reported for tests on insulators similar to those tested here except for the glass disk units. The insulators tested were of different manufacture, but had equivalent lengths, leakage paths and contours. In reference (2) both clean fog and salt fog tests were made, and in (3) the insulators were subjected to natural conditions. These data are summarized in Table VI for comparison with the present tests. Only the clean fog values are given from reference (2) since the salt fog tests resulted in the same numerical order.

Referring to Table VI, which gives the rank of the insulators as determined by the three separate investigations, it is found that there is very good agreement in the data from the CESI tests and the present tests, except for those on the long rod insulators obtained with the clean fog method in the present investigation. In the CESI tests the order is reversed for the

standard disk and fog long rod, but when the tabular values of conductivity are examined it is found that there is no real difference between the two. This is very interesting and important because it shows that results can be duplicated between different laboratories with different test methods and different contaminating mixtures when the surface conductivity is used as the basis of comparison.

Whenever a new contamination test method is proposed the final judgment as to its worth is the degree to which it can be related to results under natural pollution conditions. At the present time the only extensive data on various insulators available for natural pollution conditions are those reported from the test station at Brighton, England, where they are subjected to a highly saline atmosphere. At this station insulators corresponding to types B, C, D and E of this report have been on test first at 85 kV for 65 months and then at 85 kV plus 25%. During the first tests at 85 kV for over 5 years, both the standard and fog type long rod insulators flashed over. The tests were then continued at a 25% higher voltage on the disk units. According to the last report, the standard disk units flashed over after four months at the elevated voltage and the fog disk units were still running after eight months. These results are included in Table VI, and it is apparent that among the other data tabulated, those for the wet contaminant method agree most closely with the Brighton data. Accordingly, it may be concluded on the basis of present information that the wet contaminant test method will correlate well with service experience under seacoast conditions.

CONCLUSIONS

Two different test methods were used to compare the relative merits of five types of insulators coated with a contaminating mixture that was recently proposed in reference (1). Of the five insulator types selected, four similar ones were tested by other investigators (2,3). As a result the following conclusions can be drawn.

1. The wet contaminant test method yields lower withstand strengths than the clean fog method on the basis of salt deposit density on the insulator surface. For disk type insulators, however, a constant ratio exists between the two methods.

2. Long rod type insulators behave differently than disk under contaminated conditions, and there is a wide dispersion in the withstand data. When the lowest values are considered, they are inferior to the disk type units according to the wet contaminant method and also some tests involving natural contamination. The fog type long rod, however, has been found stronger than both the standard disk and fog disk by the clean fog method. This could be due to the large dispersion in results and lack of a sufficient number of tests.

3. When surface conductivity was used as a basis for comparison, withstand and flashover values were duplicated for disk type insulators in different laboratories, with different test methods, and slurries with different binders. It should be noted, however, that a uniform contaminant coating method was used for all of these tests.

4. The numerical order of merit of the insulators when tested by the wet contaminant method is the same as that obtained in the test under natural contamination conditions in Brighton, England.

REFERENCES

(1) - B. Macchiaroli, F.J. Turner: "A New Contamination Test Method", paper presented for the IEEE Winter Power Meeting, New York, 1969.

(2) - G. Carrara, M. Sforzini: "Analysis of Pollution Test Methods", Conference Paper No. 68CP163 PWR, presented at the IEEE Winter Power Meeting, New York, 1968.

(3) - P.J. Lambeth, J.S.T. Looms, G. Leroy, Y. Porcheron, G. Carrara, M. Sforzini: "The Salt Fog Artificial Pollution Test", report presented at the meeting of CIGRE, 1968.

TABLE I

MAIN CHARACTERISTICS OF TESTED STRINGS

Insulator Type	No. of Units	Overall Length mm	Leakage Path mm
A. High Creepage Glass Disk	8	1320	3960
B. Fog Disk	8	1320	3450
C. Standard Disk	9	1314	2630
D. Fog Long Rod	1	1305	2840
E. Standard Long Rod	1	1270	1990

TABLE II

WET CONTAMINANT METHOD

COMPARISON OF INSULATOR TYPES AT A WITHSTAND VOLTAGE OF 84 KV

Insulator Type	NaCl		Slurry Conductivity		Salt Deposit		Surface Conductivity	
	g/l	Comp. With Insulator A	mS/cm	Comp. With Insulator A	mg/cm^2	Comp. With Insulator A	µS	Comp. With Insulator A
A. High Creepage Glass Disk	8.2	1	10.8	1	.050	1	50	1
B. Fog Disk	7.3	.89	9.6	.89	.045	.90	29	.58
C. Standard Disk	4.5	.55	6.4	.59	.034	.68	21	.42
D. Fog Long Rod	3.6	.44	5.5	.51	.016	.32	17	.34
E. Standard Long Rod	3.0	.37	4.5	.42	.014	.28	13	.26

TABLE III

CLEAN FOG METHOD

COMPARISON OF INSULATOR TYPES AT A WITHSTAND VOLTAGE OF 84 KV

Insulator Type	Salt Deposit		Surface Conductivity	
	mg/cm^2	Comp. With Insulator A	µS	Comp. With Insulator A
A. High Creepage Glass Disk	.070	1	49	1
D. Fog Long Rod	.064	.91	34	.69
B. Fog Disk	.062	.89	29	.59
C. Standard Disk	.048	.69	21	.43
E. Standard Long Rod	.040	.57	20	.41

TABLE IV

CLEAN FOG METHOD

AVERAGE TIME FOR REACHING A STEADY VALUE OF SURFACE CONDUCTIVITY

Insulator Type	Minutes
A. High Creepage Glass Disk	50
B. Fog Disk	45
C. Standard Disk	35
D. Fog Long Rod	25
E. Standard Long Rod	20

TABLE V

COMPARISON OF SALT DEPOSIT DENSITIES CORRESPONDING TO WITHSTAND VALUES OF 84 KV

Insulator Type	Clean Fog (mg/cm^2)	Wet Contaminant (mg/cm^2)	Ratio $\frac{\text{Fog}}{\text{Wet Contaminant}}$
A. High Creepage Glass Disk	.070	.050	1.4
B. Fog Disk	.062	.045	1.38
C. Standard Disk	.048	.034	1.41
D. Fog Long Rod	.064	.016	4.0
E. Standard Long Rod	.040	.014	2.86

TABLE VI

COMPARISON AMONG DIFFERENT INSULATORS

Insulator Type	Surface Conductivity Corresponding to 84 kV						Time to Flashover in Months	
	Wet Contaminant		Clean Fog		CESI - Clean Fog*		Natural Tests at Brighton**	
	µS	Rank	µS	Rank	µS	Rank	at 85 kV	at 85 kV + 25%
A. High Creepage Glass Disk	50	1	49	1				
B. Fog Disk	29	2	29	3	27	1	W 65	W 8
C. Standard Disk	21	3	21	4	18	3	W 65	4
D. Fog Long Rod	17	4	34	2	19	2	36	
E. Standard Long Rod	13	5	20	5	13	4	8	

* - Data from reference (2) - The values correspond to insulators having about the same characteristics.

** - Data from reference (3) - The values correspond to insulators having about the same characteristics.

W - Withstand

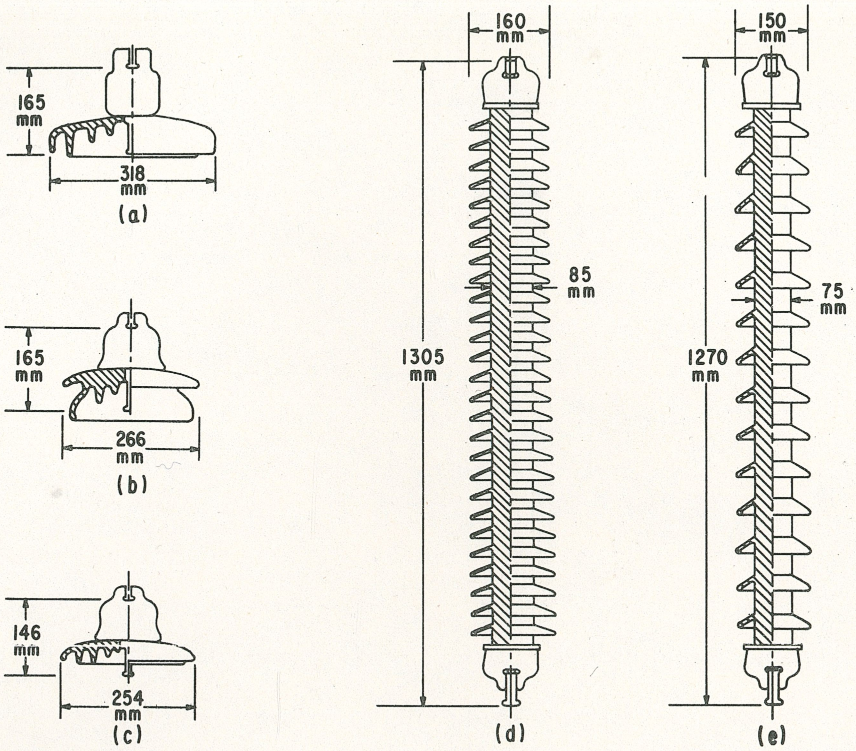

Fig. 1. Tested Insulators.

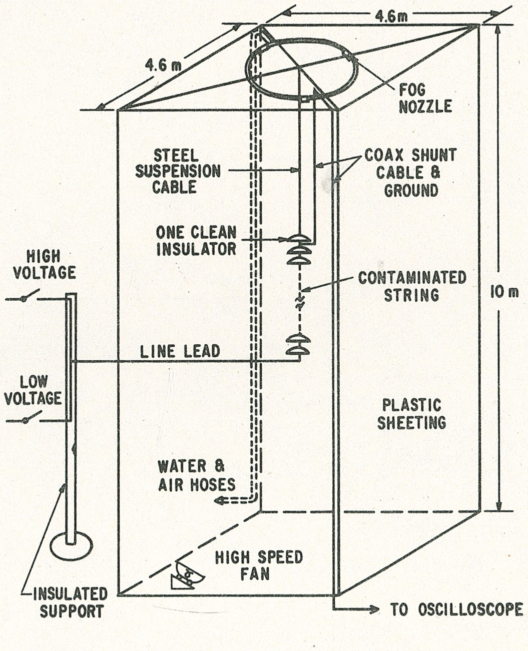

Fig. 2. Fog Chamber Arrangement.

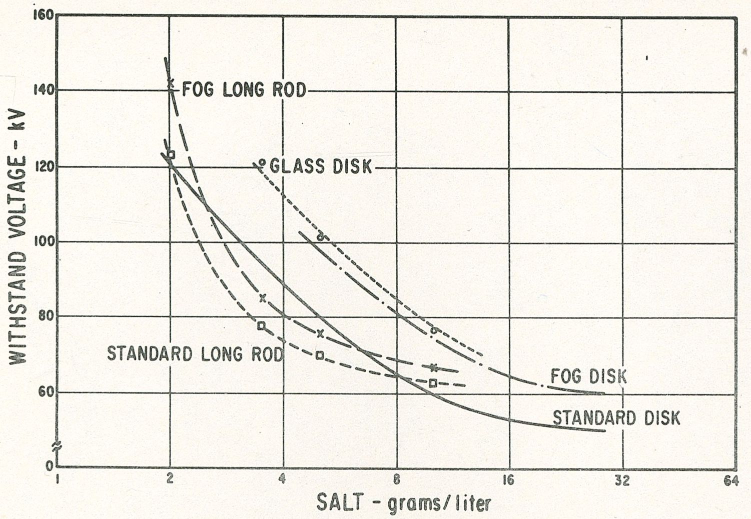

Fig. 3. Wet Contaminant Method - Withstand Voltage Versus the Salt in the Slurry for Disk and Long Rod Insulators. Fog and standard disk curves reproduced from reference (1).

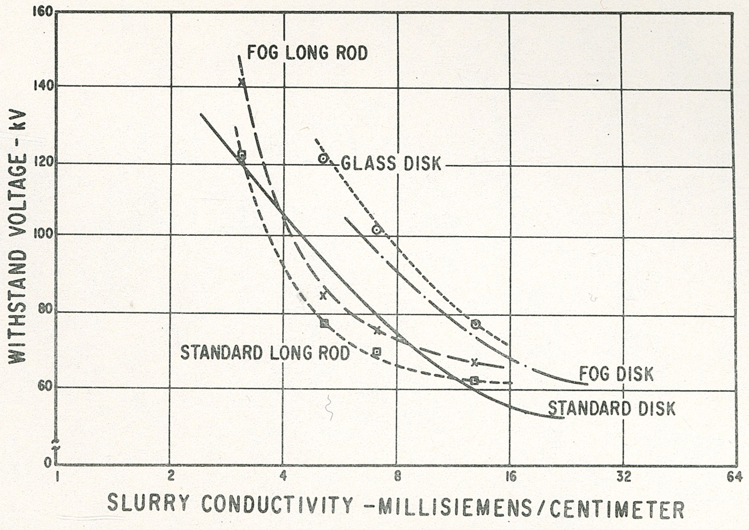

Fig. 4. Wet Contaminant Method - Withstand Voltage Versus Slurry Conductivity for Disk and Long Rod Insulators. Fog and standard disk curves reproduced from reference (1).

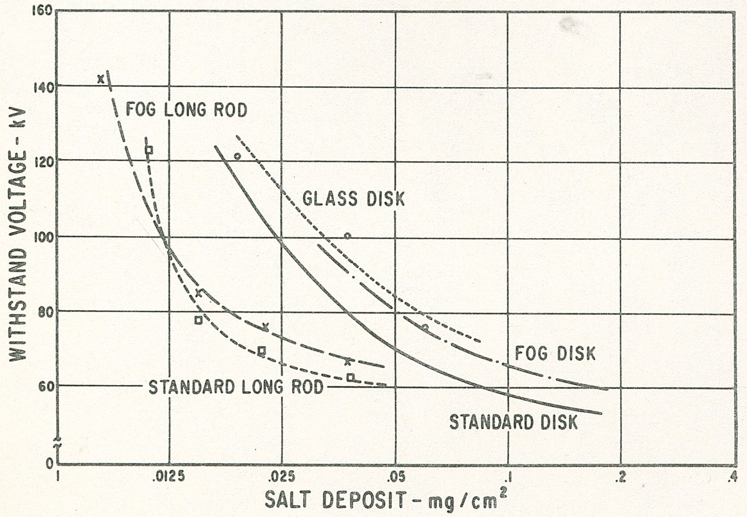

Fig. 5. Wet Contaminant Method - Withstand Voltage Versus the Salt Deposit Density. Fog and standard disk curves reproduced from reference (1).

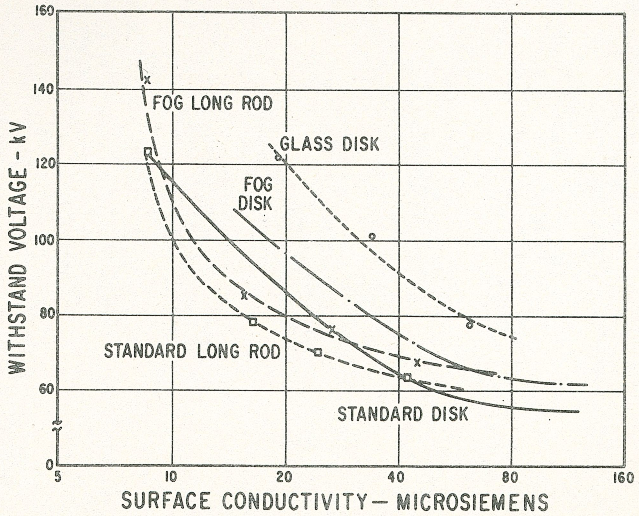

Fig. 6. Wet Contaminant Method - Withstand Voltage Versus the Surface Conductivity for Disk and Long Rod Insulators. Fog and standard disk curves reproduced from reference (1).

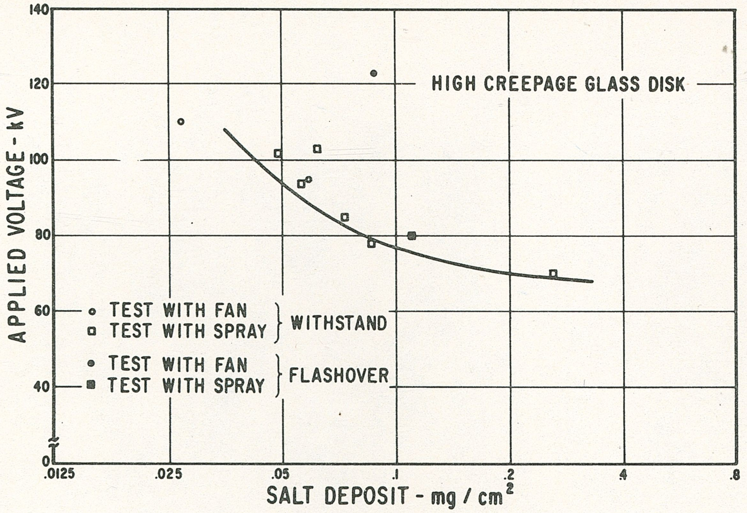

Fig. 7. Clean Fog Method and High Creepage Glass Disk Insulators - Withstand Voltage Versus Salt Deposit Density.

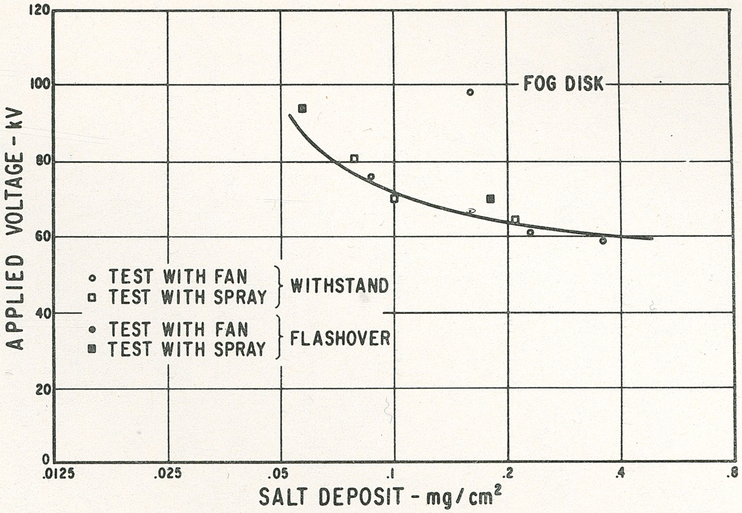

Fig. 8. Clean Fog Method and Fog Disk Insulators - Withstand Voltage Versus Salt Deposit Density.

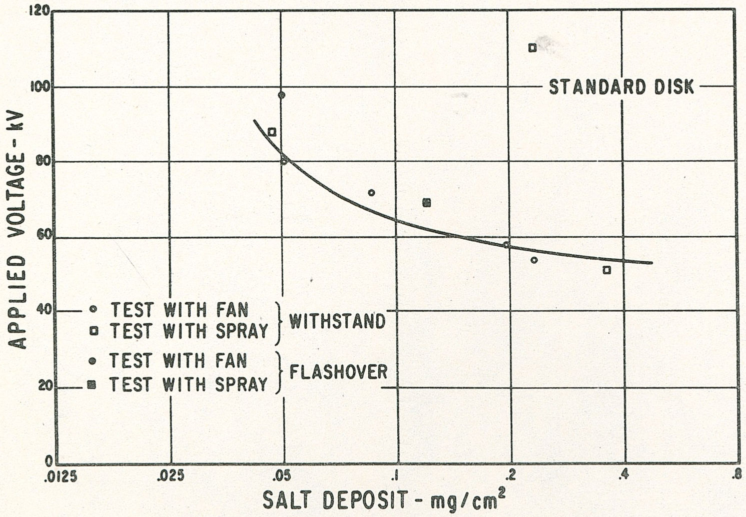

Fig. 9. Clean Fog Method and Standard Disk Insulators - Withstand Voltage Versus Salt Deposit Density.

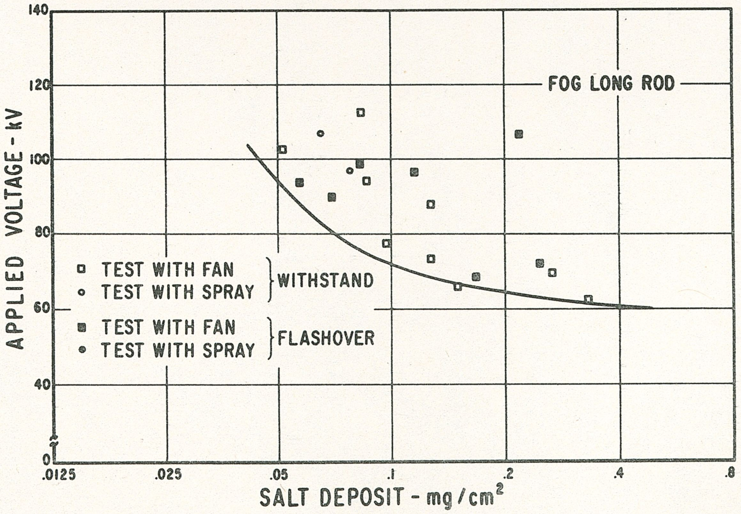

Fig. 10. Clean Fog Method and Fog Long Rod Insulators - Withstand Voltage Versus Salt Deposit Density.

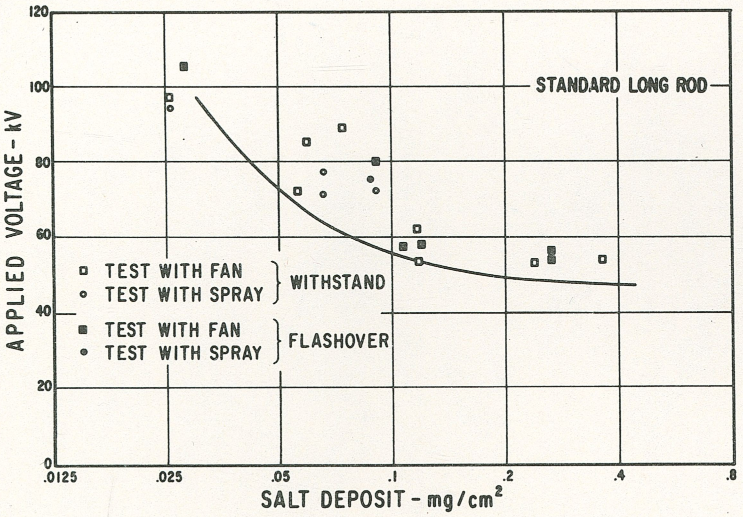

Fig. 11. Clean Fog Method and Standard Long Rod Insulators - Withstand Voltage Versus Salt Deposit Density.

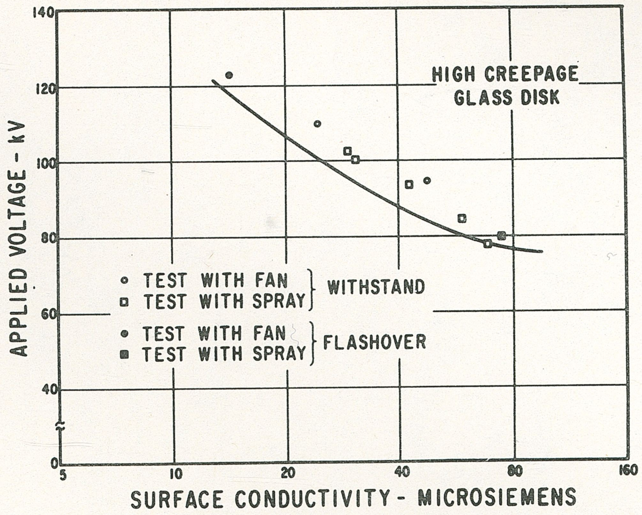

Fig. 12. Clean Fog Method and High Creepage Glass Disk Insulators - Withstand Voltage Versus Surface Conductivity.

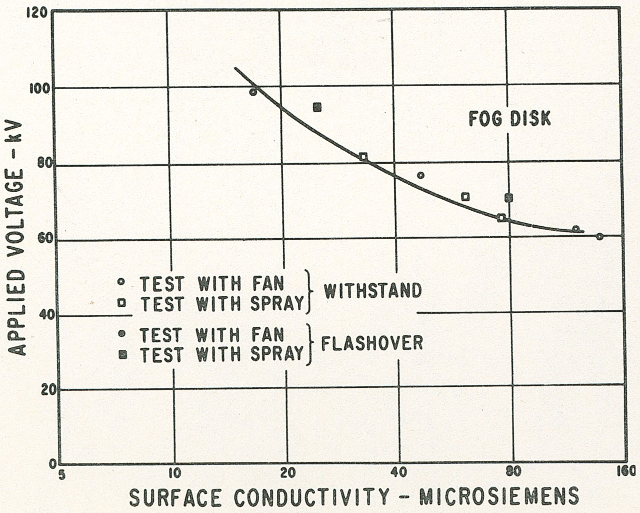

Fig. 13. Clean Fog Method and Fog Disk Insulators - Withstand Voltage Versus Surface Conductivity.

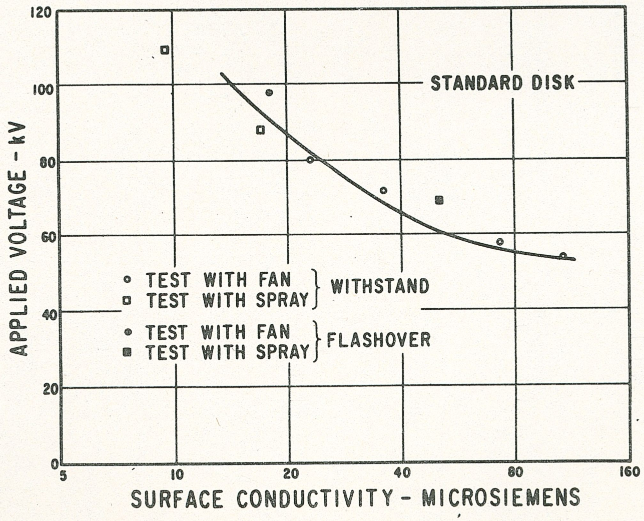

Fig. 14. Clean Fog Method and Standard Disk Insulators - Withstand Voltage Versus Surface Conductivity.

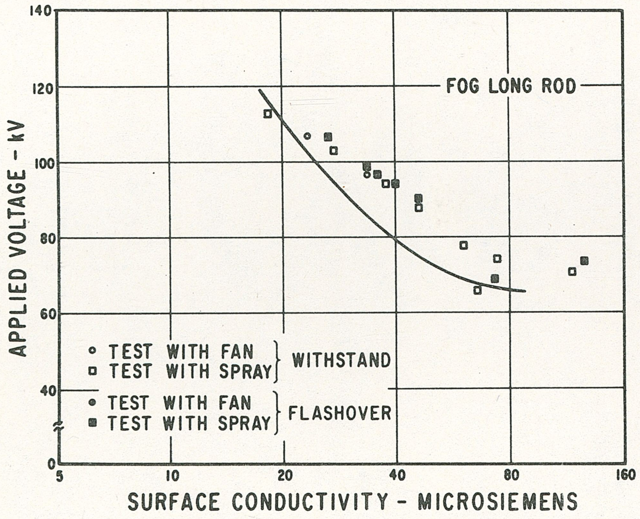

Fig. 15. Clean Fog Method and Fog Long Rod Insulators - Withstand Voltage Versus Surface Conductivity.

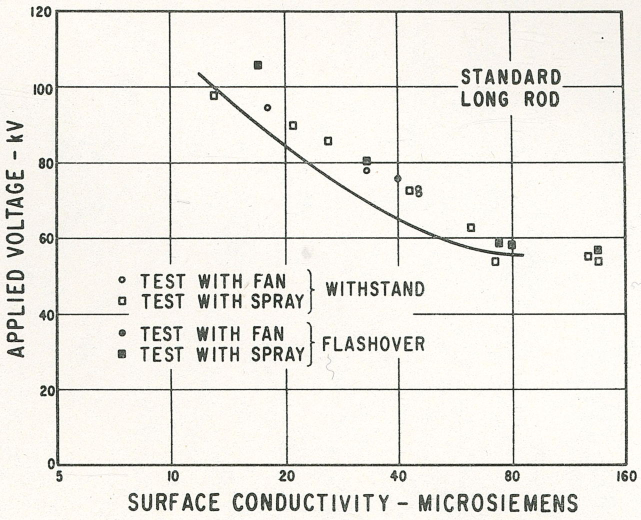

Fig. 16. Clean Fog Method and Standard Long Rod Insulators - Withstand Voltage Versus Surface Conductivity.

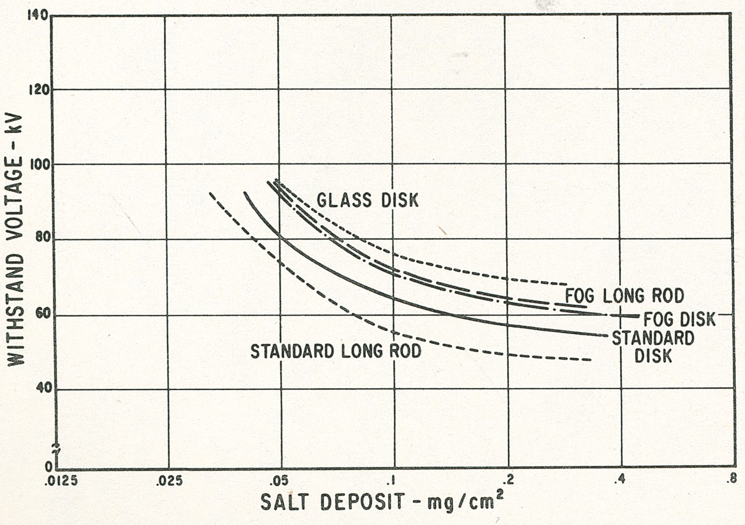

Fig. 17. Clean Fog Method - Withstand Voltage Versus Salt Deposit Density for Disk and Long Rod Insulators.

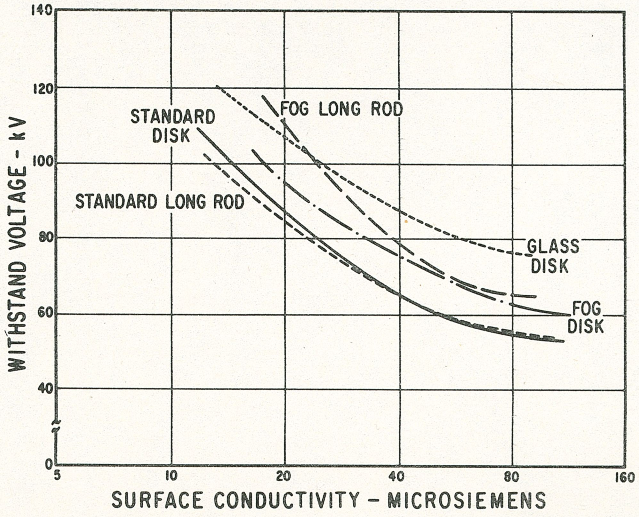

Fig. 18. Clean Fog Method - Withstand Voltage Versus Surface Conductivity for Disk and Long Rod Insulators.

Survey of Literature in 1968
by W.T. Starr

The state of understanding of the mechanism of flashover of polluted insulation is revealed by Zoledziowski's paper (1), and the discussion following it. Z. fits his data to the equation $(V^2-V_o^z)t = \frac{Ce}{3} r^2 L^3$ where V is the applied unidirectional voltage, V_o is the minimum voltage below which a flashover will not occur, t is the time to flashover, C is a constant, e is the energy needed for discharge production, r is the pollution resistance per unit length, and L is the distance between electrodes. Zoledziowski believes that the discharge propagates in air, not steam, that a dry band is not required for discharge initiation, and that the discharge starts to propagate at zero time.

Salthouse (2) has studied the processes which result in the initiation of dry bands on polluted insulators. Above a critical temperature rise (ΔTc) which is less than 1°C, the resistance in one location increases much more rapidly than in others. ΔTc corresponds to a power dissipation density of about $5 mW/cm^2$.

Kawai(3) has studied the natural conditions of humidity, fog and temperature which precipitate flashover and has determined withstand voltage of a variety of types of suspension insulators as a function of salt deposit density. Light rain or fog after several hours of high humidity minimizes flashover voltage. A steam fog artifically reproduces this condition.

Johnson et al(4) have reported on an intensive study of the conditions leading to flashover of heavily contaminated insulator strings leading to design criteria for a 500 kV line in Victoria. Contamination is by a salt laden smoke and fog, underside contamination controls. KV/insulator for 60 Hz flashover varies linearly with the logarithm of salt concentration being 1.3 in/Kv at 0.2 and 2.1 in/KV at 10 mg/cm^2. A mechanism is suggested and results of high speed motion picture corollation with surging currents are described.

Phelps, Owens, and Foti (5) have devised a contaminant and testing proceedure for evaluating insulator designs for EHV station use. A spray coating containing China clay, bentonite and salt is sprayed on the insulators to produce a deposit with a certain ratio of conductivity to thickness. After drying, the insulators are assembled in a salt fog chamber, thoroughly wetted and held at 1.1 X nominal line to ground for one hour. Then the voltage is increased and the flashover voltage noted.

Fujitaka et al (6) have developed a contaminant and test proceedure for pollution tests of insulators. The salt content of the contaminant is correlated with the amount known to exist in the application area. Power frequency voltage is increased to flashover in 30 seconds. Current available must exceed 5 amperes. Design data for station insulators are given as a function of ambient contamination.

Seven discussors (7) provide data on economic and technical aspects of live line washing of H.V. insulators as against greasing in polluted areas. Discussions of two papers, one favoring one approach and one the other are combined.

Niemi and Mitchell (8) describe a silicone plastic protective coating for suspension insulators to be used in polluted atmospheres. Excellent adhesion is claimed. The surface remains water repellent after UV aging. A 15 mil (0.375 mm) coating is being applied for field trials.

Billings and Storey (9) discuss two methods for determination of the effects of resistive glazes, pollution, dry bands, capacitor foils on the voltage distribution of insulators. One is a numerical method and the other is an electrolytic tank analogue. A resistive glaze can significanly decrease the tendency toward dry band formation despite its conductance being equal to (no more than) capacitive susceptance. Several interesting flux plots are included.

Ely and Roberts (10) examine the switching and impulse flashover of air gaps and insulators in a polluted atmosphere. Rod to rod and rod to plane gaps were not significantly affected. For insulators the 50% FOV dropped 240 kV for each 10 to 1 increase in salinity (35 X 2200 μs wave.) (10 unit standard disc or rod insulator)With prior alternating voltage energization, the FOV was considerably reduced (-60 kV with disc and -100 kV with rod). At a soluity of 5 g/l the FOV of the disc string is 600 kV while the rod type is 400 kV.

It is commonly assumed that the switching surge flashover characteristics of insulators and gaps are independent of pre-existing direct voltages. Watanabe (11) tested gaps and insulator strings with critical (50%) flashover (CFO) the range of 1 to 1.8 MV crest and a dc voltage of 400 kV. When the direct voltage was applied to same electrode as the surge, the effect was in the range of 2 - 7%, with neg. dc lowering positive surge CFO's and increasing negative switching surge CFO's. With positive switching surge, the effect is opposite. When the direct and switching surge voltages are applied to the different electrodes of the pair, the switching surge CFO was lower than without the direct voltage by an amount slightly less than the applied dc voltage.

Udo and Watanabe (12) have compared dry and wet sparkover characteristics of rod and sphere gaps and insulator strings with direct and 50 Hz voltage. Snow conditions on insulators are also included. Sphere and rod-rod gaps are essentially the same for direct and 50 Hz voltages. For rod-plane, positive and 50Hz crest sparkover voltages are similar. The influence of wet conditions is large for negative and small for positive rod. The direct voltage withstand of an insulator string is smaller for negative than for positive voltages and may be 50% of the dry value when wet and 25% when completely covered with snow.

For simplicity it is often assumed that the critical flashover voltage of a switching surge (S.S.) alone is the same as the c.f.o. for a s. s.superimposed on a 60 Hz. Udo,Tada and Watanabe (13) have evaluated this assumption and find that for a positive s.s. it is definitely true. This is fortunate for positive s.s. strength is lower than negative. Data are given for rod-rod, sphere to plane, bundle to tower. Data relative to humidity corrections and standard deviation are important also.

Paris and Cortina (14) have determined the influence of insulators in a large air gap on the switching surge and lightning surge flashover characteristics. Twenty electrode arrangements and four suspension insulator types were tested. For 1.2 X 50 μs negative polarity impulse, rod to plane and rod to rod gaps are most affected by the presence of insulators. For switching surges, the negative-wet combination in general is more affected by the presence of insulators than either negative dry or positive dry or wet. Sufficient data are given to cover a wide range of service conditions.

Okada and Kimoto (15) demonstrate how to improve the reliability of capacitance pin suspension insulators by applying a "proof" test to all porcelains and using those that pass for production. The proof test is mechanical stress resulting from applying hydraulic pressure into the cup of the insulator before the cap or pin is applied.

Taylor and Newport (16) examine the status of information and theory of the fracture mechanism of porcelain as it applies to suspension insulators.

Rogers (17) discusses the electrical and mechanical factors involved in the design of epoxy high voltage bushings. He includes two volt-time curves for epoxy compounds, one at room temperature and the other at 90°C. The asymptotic stress at 90°C is 270 volts per mil (.10^4-10^5 minutes).

Kappeler (18) describes the design and properties of resin bonded paper bushings for EHV applications. A major advantage over porcelain is the reduction of length of the end which dips into the transformer oil which is made possible by exposing the ends of the built in equalizers.

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